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Penetrating Radiation: Applications at Los Alamos National Laboratory

Penetrating Radiation Systems and Applications XIV

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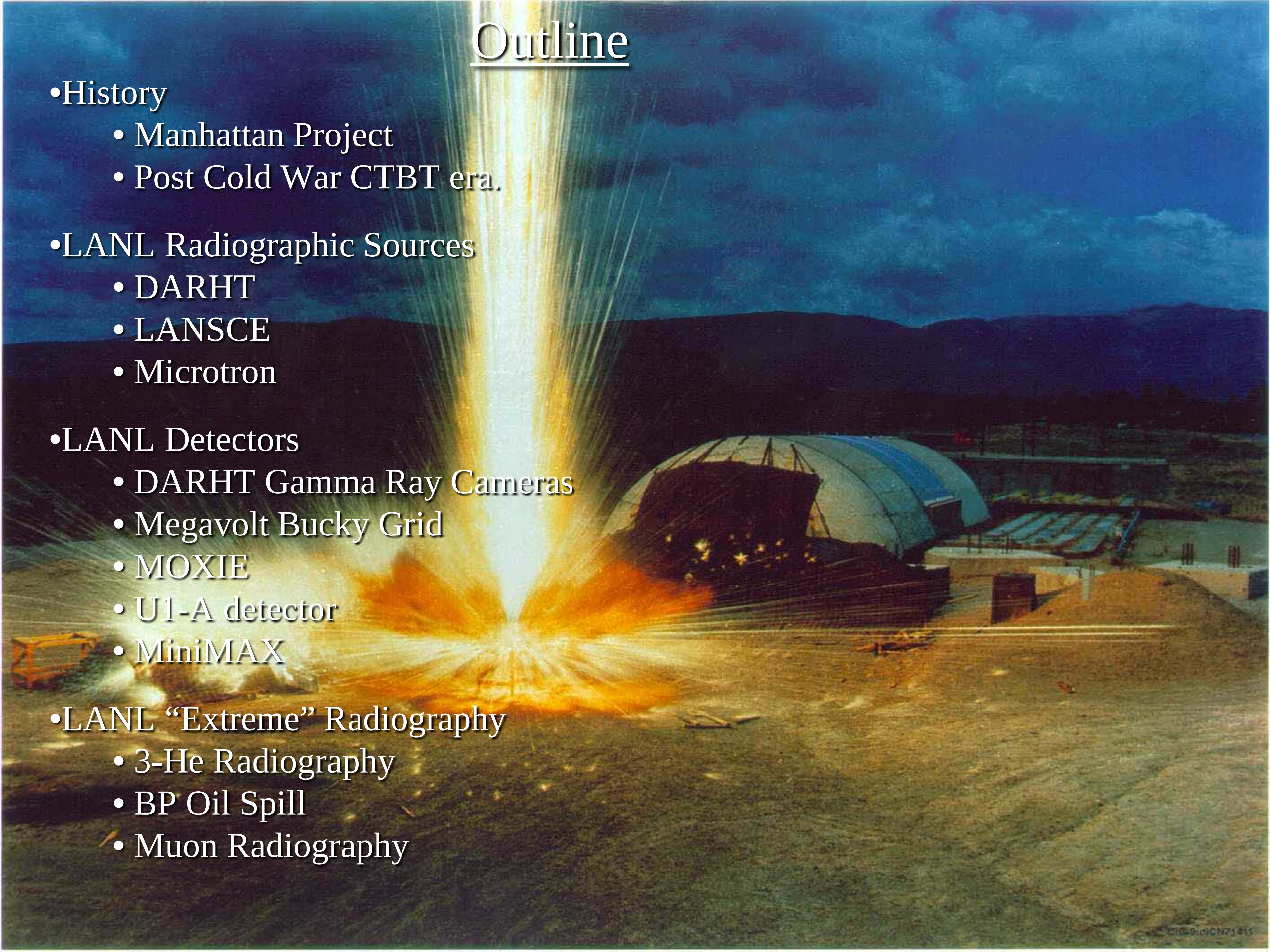


Outline

- History
  - Manhattan Project
  - Post Cold War CTBT era.

- LANL Radiographic Sources
  - DARHT
  - LANSCE
  - Microtron

- LANL Detectors
  - DARHT Gamma Ray Cameras
  - Megavolt Bucky Grid
  - MOXIE
  - U1-A detector
  - MiniMAX

- LANL “Extreme” Radiography
  - 3-He Radiography
  - BP Oil Spill
  - Muon Radiography

Early Flash Radiography at Los Alamos

"In the early part of the program the chief objective was to adapt X-ray techniques to large scale implosions.   It was proposed to actually follow the course of the implosion by detecting the incidence of the X-rays as a function of time, using a grid of small Geiger counters. *The principal aims of the program were: (1) reliable action of the counters, and (2) reduction of the amount of scattered radiation. These objectives were pursued relentlessly, but because of the great technical difficulties, with very little real success, the program was dropped in March, 1945."* –Project Y History.

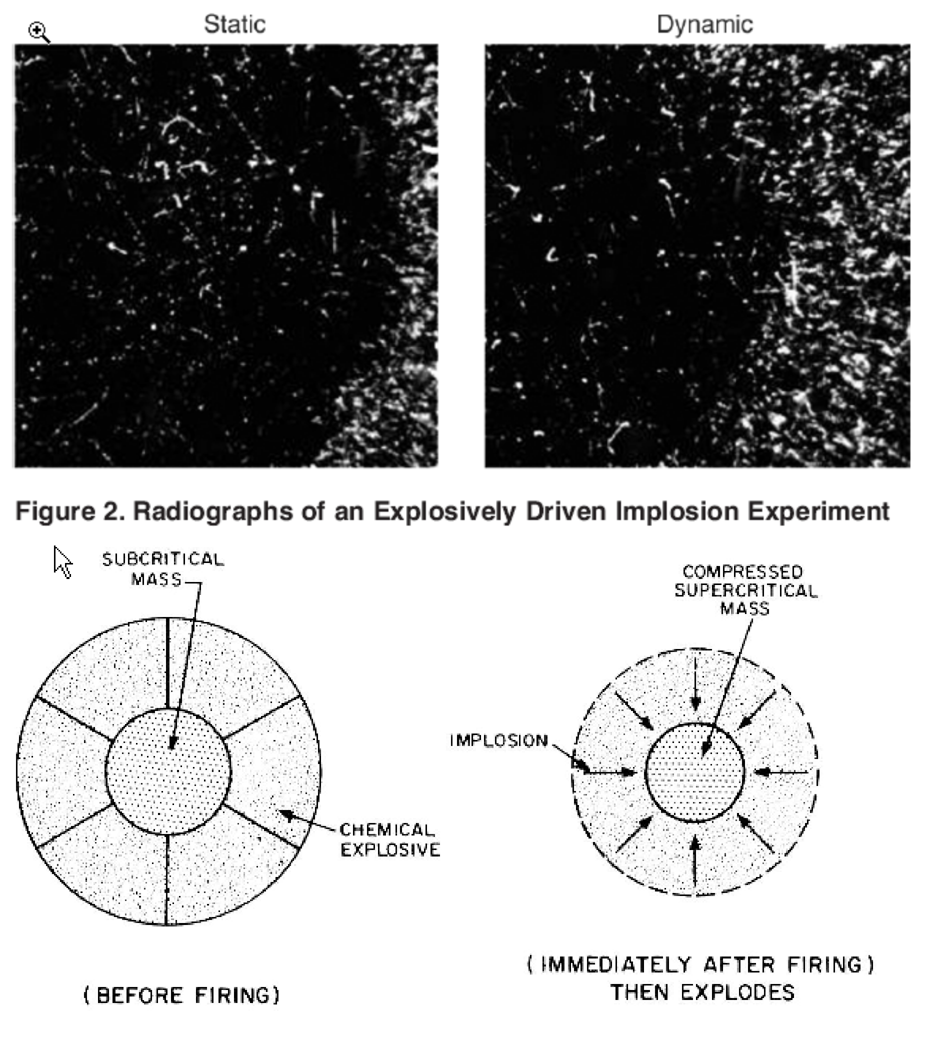


Figure 2. Radiographs of an Explosively Driven Implosion Experiment

What is Hydrotesting?

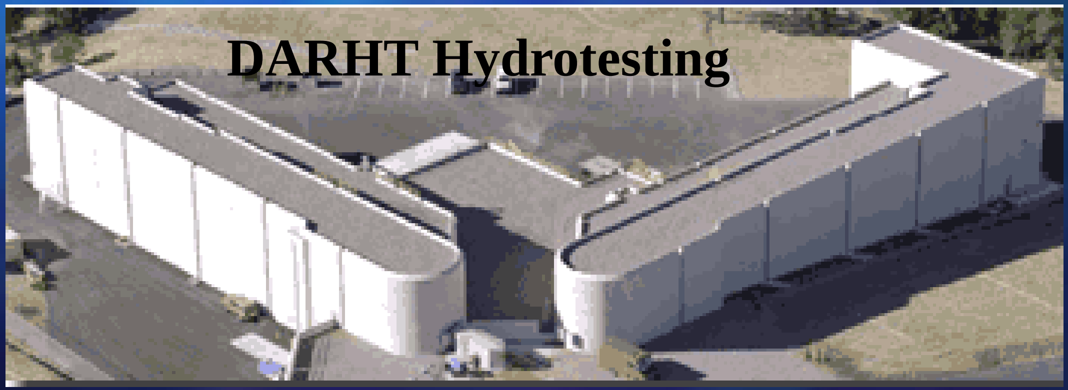
"A dynamic, integrated systems test of a mock-up nuclear package during which high explosives are detonated and the resulting motions and reactions of materials and components are observed and measured. Fast diagnostics systems include: flash radiographic cameras, electrical pins, high speed photography, and interferometry ."

-DOE definition

Why DARHT?

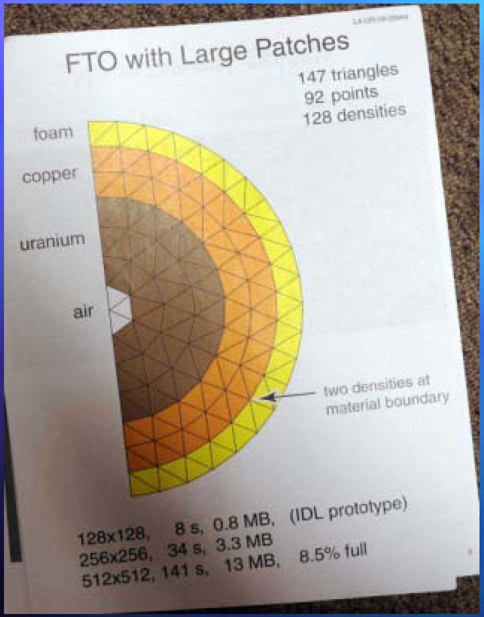
Faced with a de facto CTBT, on August 11, 1995 President Clinton stated:

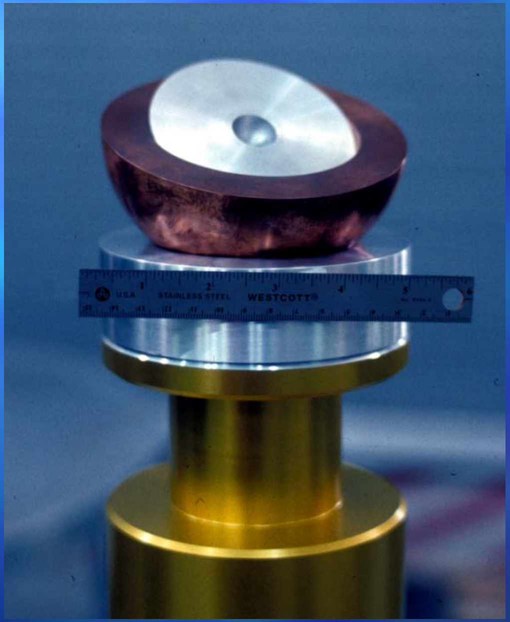
“I consider the maintenance of a safe and reliable nuclear stockpile to be a supreme national interest of the United States.”

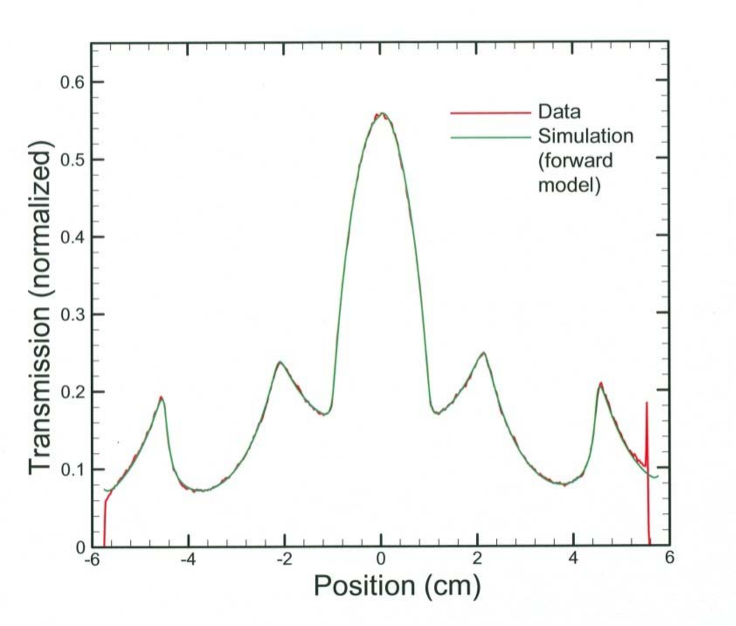


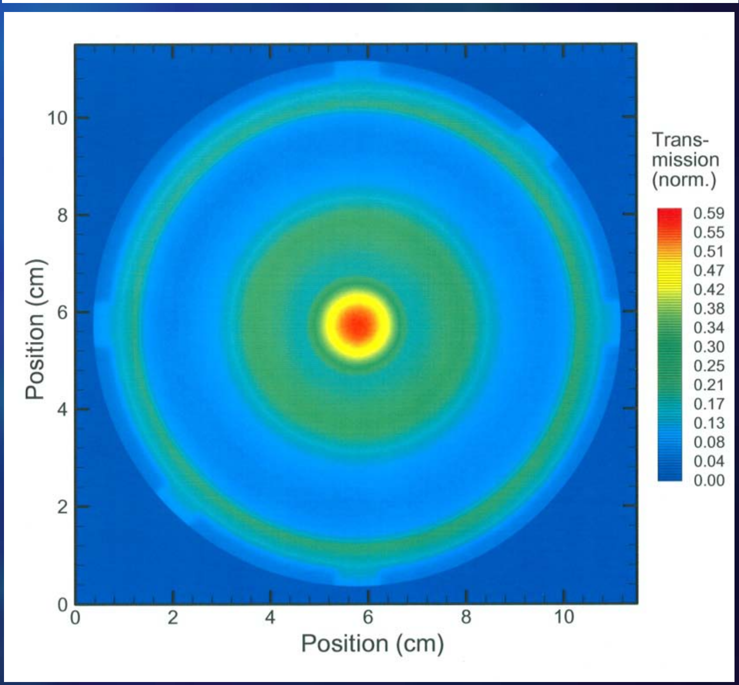
Density Reconstructions

- 1% density reconstructions on FTO => stockpile certification without nuclear testing.
- Uses advanced, forward modeling (BIE) techniques.



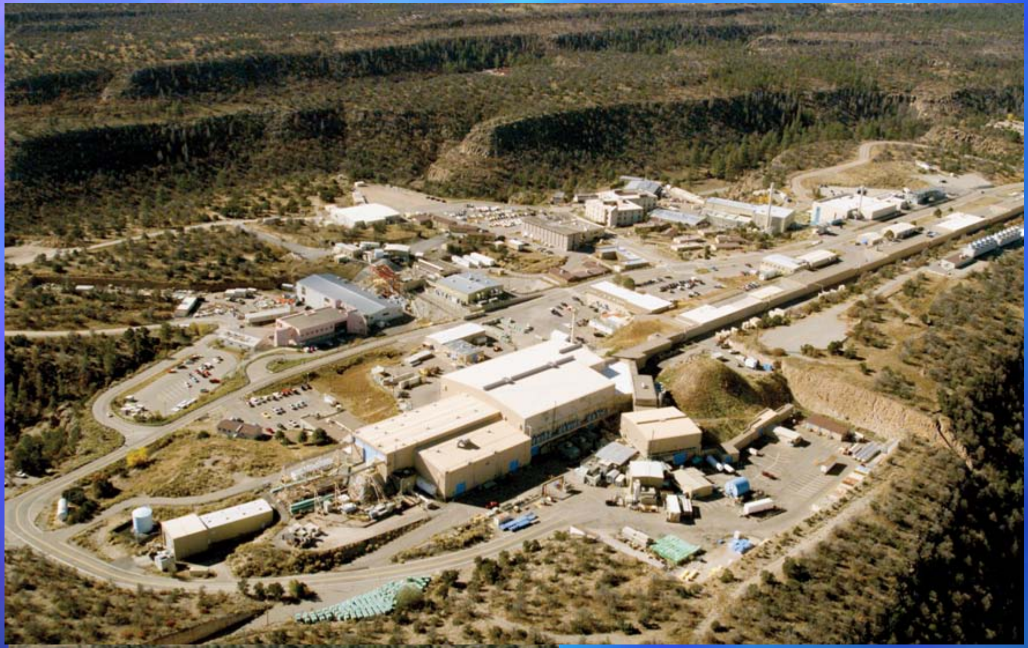




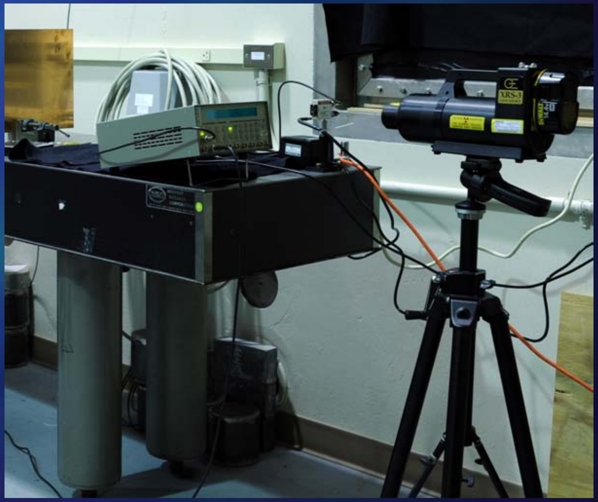


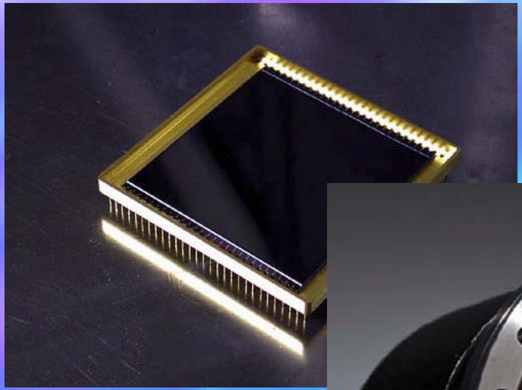
Analysis of FTO Data: Scatter Levels At DARHT And Performance of An Anti-Scatter Grid. Defense Research Review, Vol. 17.1. 2009.

Los Alamos Radiographic Sources



- DARHT – 20 MeV Flash X-rays.
- LANSCE – 800MeV Protons.
- Microtron – 6,9, and 20MeV bremsstrahlung x-rays.
- Isotopes – Co-60, Cs-137, Co-57 etc.
- Portable Systems – Golden XRS-3, JME Betatron, A&E PORTACS.



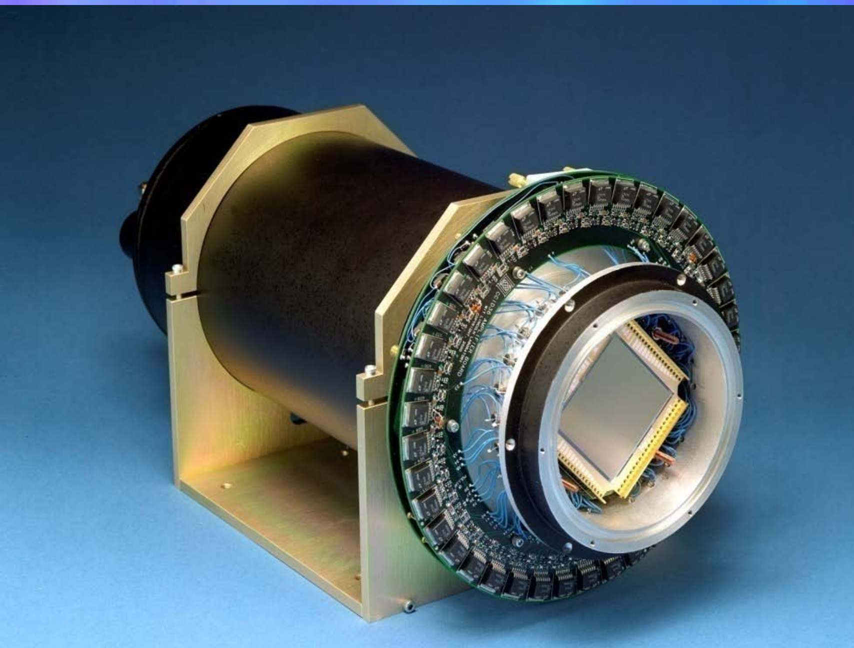


DARHT 1st Axis Camera

- Large format γ-ray camera. Designed for high DQE (>50%) and low Compton scatter blur to match DARHT.
- Uses Spectral Instruments TE-cooled camera with a Fairchild, 4096x4096 back-thinned CCD, with 15μ pixels.
- Uses large (55cm diam.), segmented, LSO array.
- Uses heavy blast protection "house".

The DARHT Camera. LA-UR-03-4985. Los Alamos Science Magazine Vol. 28. Los Alamos National Laboratory. 2003.

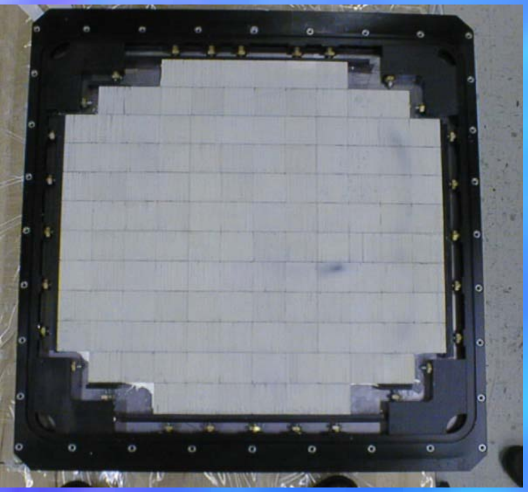
DARHT 2nd Axis Camera

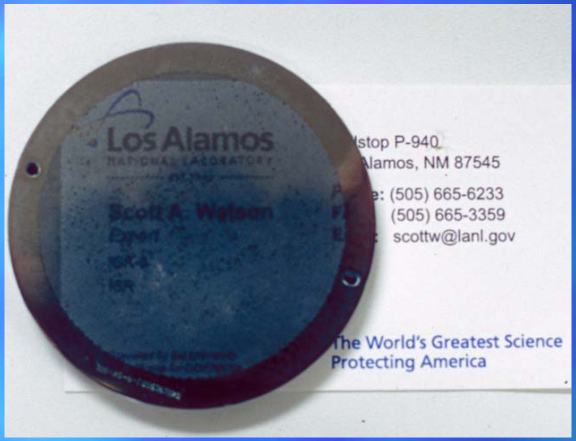


- 4 frame design, 40% QE.
- Designed for very high QE, low blur, and high frame rate to match DARHT II.
- Uses custom MIT-LL CCD's.
- Employs advanced metal grid scintillator construction.
- Captures radiographs at 2 million frames per second.
- First hydrotest movie – shot 3618.
- First movie of W-88 implosion – shot 3648.

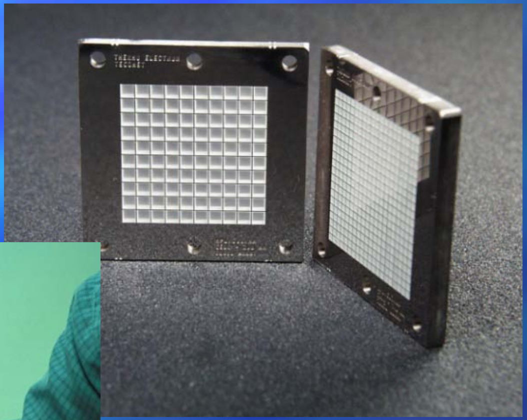
Lincoln Laboratory High-Speed Solid-State Imager Technology. International Conference On High Speed Photography and Photonics. SPIE Vol. 6279, 62791k. 2006.

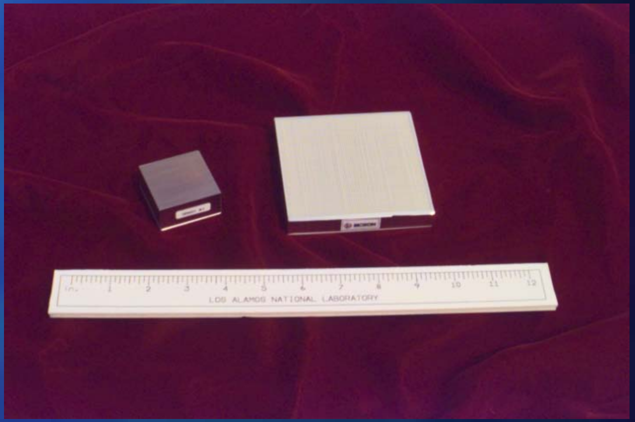
Segmented Scintillators

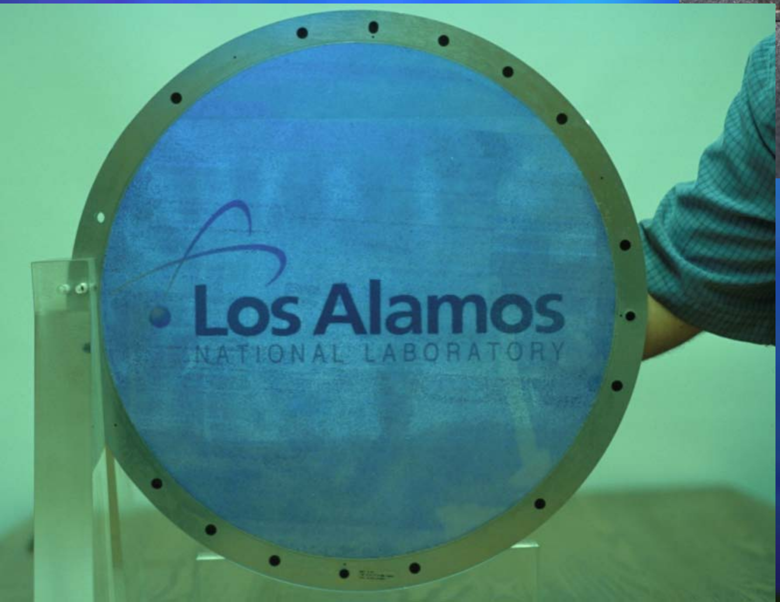


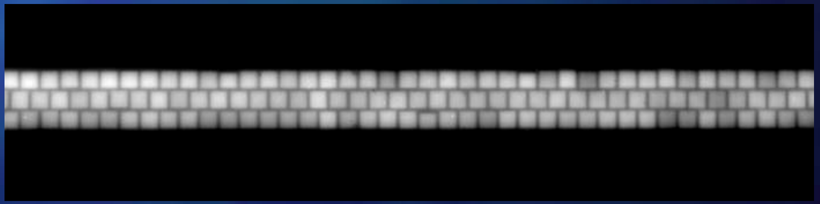


- New construction techniques have been developed, including: sawcutting, growth in metal matrix, assembly in focused metal matrix, and photo-etching.
- Very large scintillators are now being fabricated.



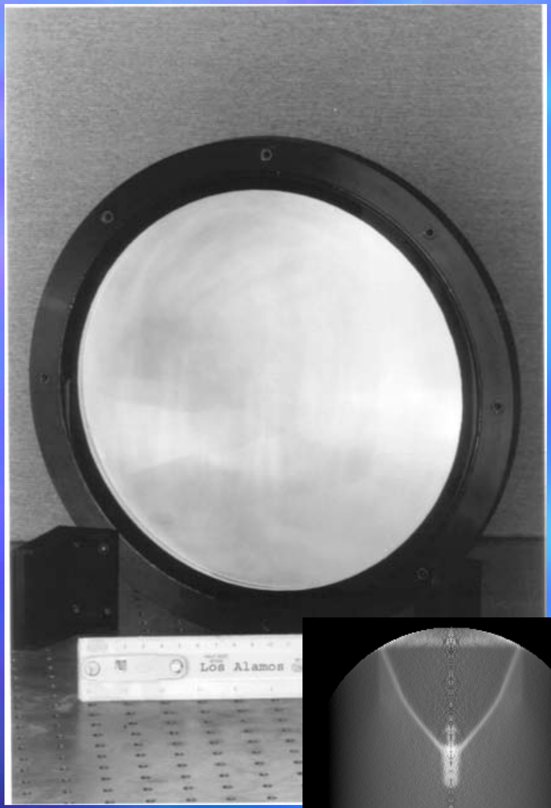




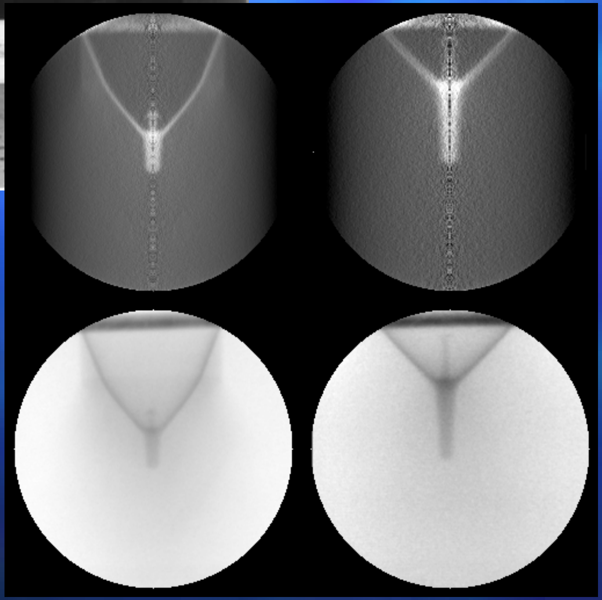


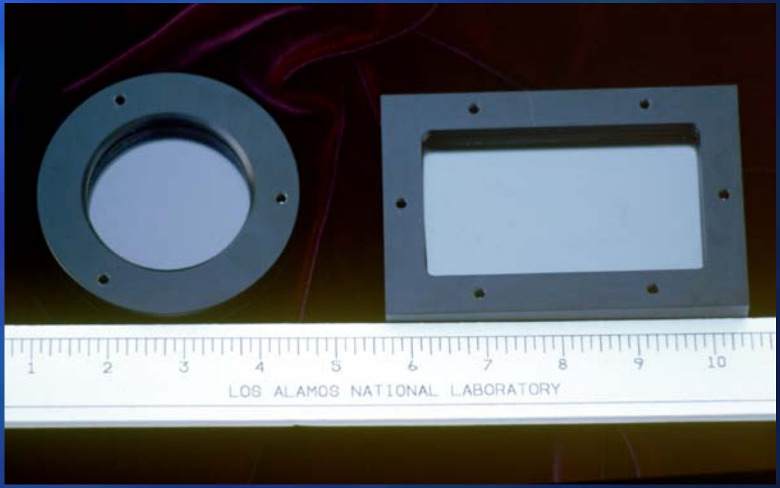
Cost Effective Segmented Scintillating Converters for Hard X-Rays. International Symposium on Optical Science, Engineering and Instrumentation, SPIE, 1996.

Monolithic Scintillators



- Low cost alternative to segmented scintillators.
- Can be expended: e.g. PHERMEX, U1-A.
- Thin scintillators have demonstrated higher resolution than film at megavolt energies.

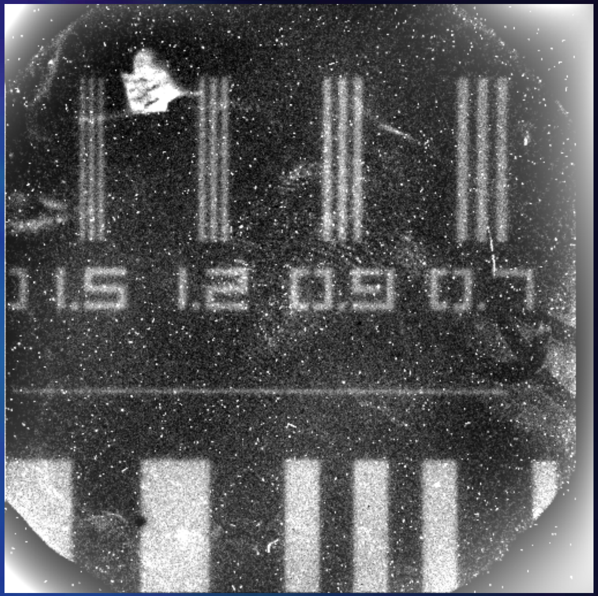


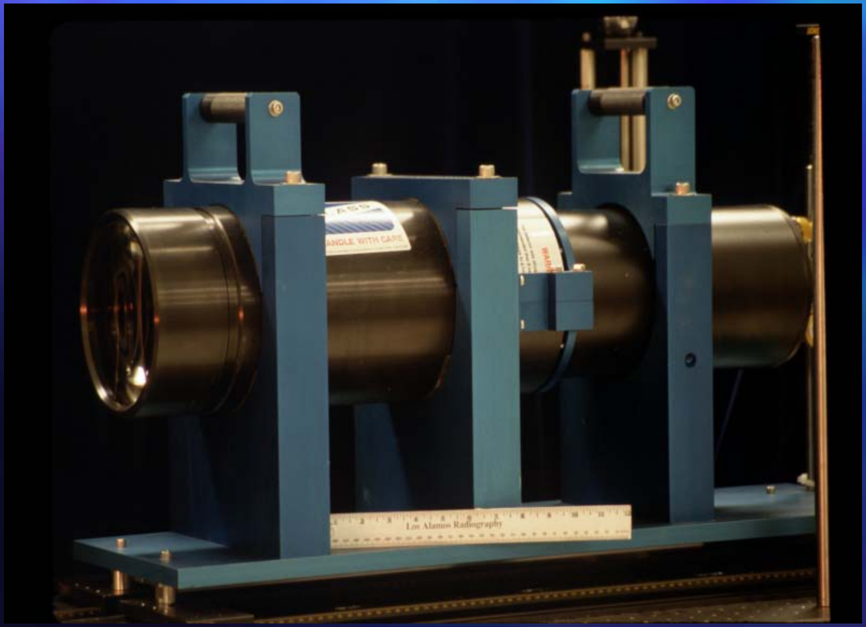


The Pulsed High-Energy Radiographic Machine Emitting X-Rays (PHERMEX) Flash Radiographic Camera. 22nd International Congress on High-Speed Photography and Photonics, 1996.

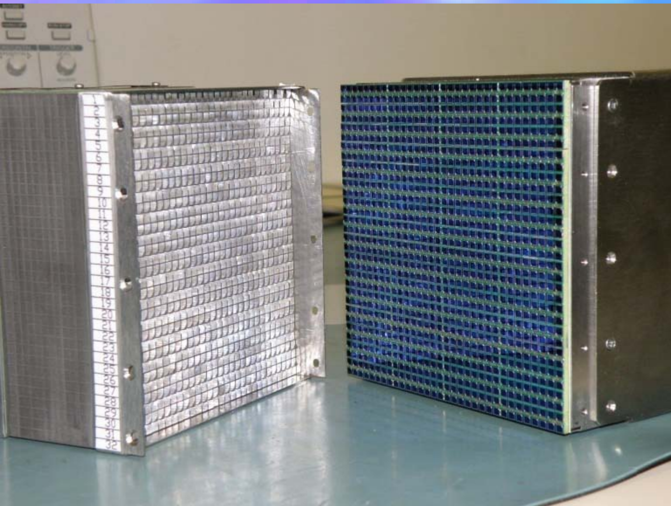
U1-A Camera

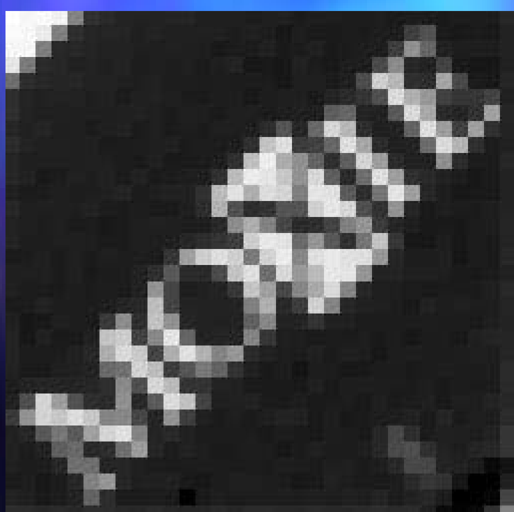
- Excellent resolution (3lp/mm at MeV energies).
- Optimized for subcritical shots at the Nevada Test Site.
- Small format (15cm diam.), monolithic, LSO scintillator.

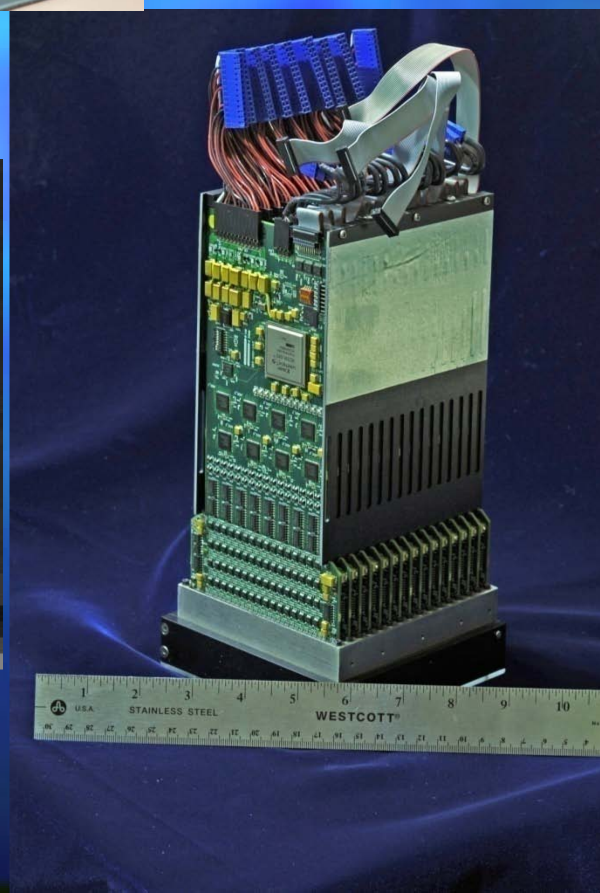




MOXIE



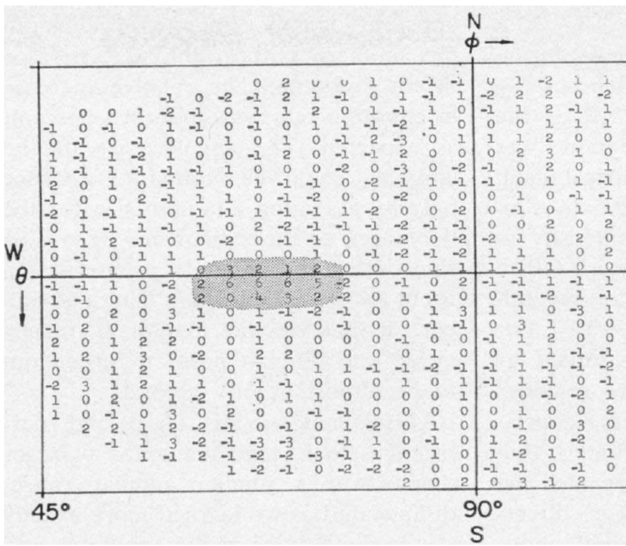




- World’s fastest movie camera.
- Uses unique, in-line, modular design.
- Designed for very high QE (50%), high speed 20Mfps, and large number of frames (4096).
- Can use protons, visible light, or x-rays.
- 32 x 32 pixels x 4096 frames.

Muon Tomography

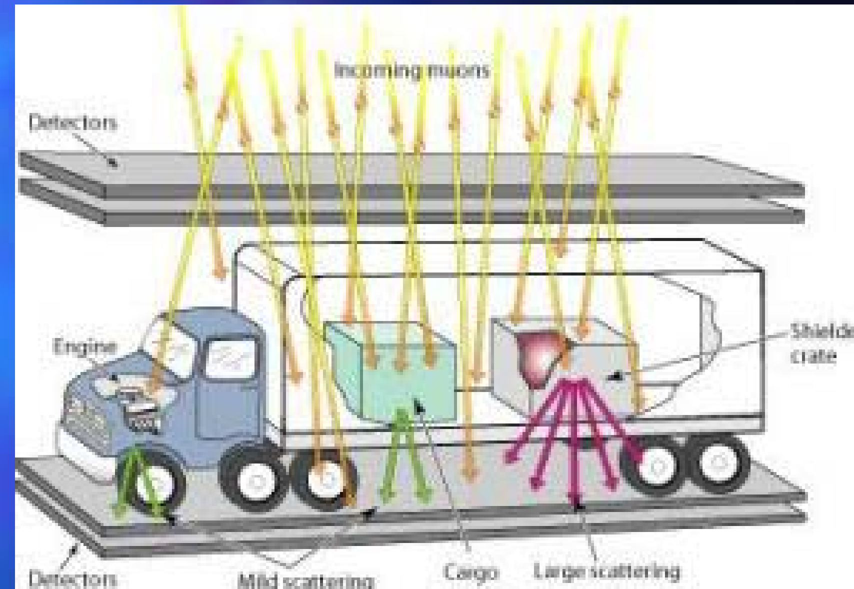
- First proposed by Luis Alvarez et al. in 1965.
- Used cosmic rays to interrogate pyramids in search of hidden burial chambers.
- Initial attempt stopped during Arab-Israel War 1967.
- First use of synthetic radiography.



Scientist as detective: Luis Alvarez and the pyramid burial chambers, the JFK assassination, and the end of the dinosaurs. **Wohl. C. G.. American Association of Physics Teachers. 2007.**

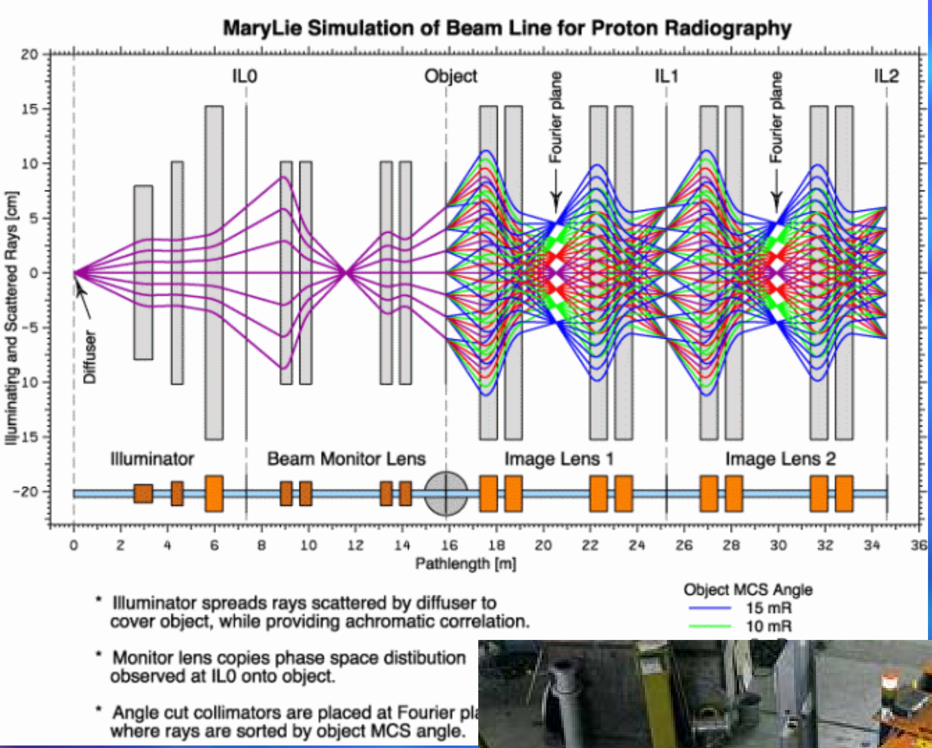
Muon Tomography

- Completely passive.
- Penetrates thick and dense objects.
- Relatively inexpensive.
- Measures scattering angle of individual particles.

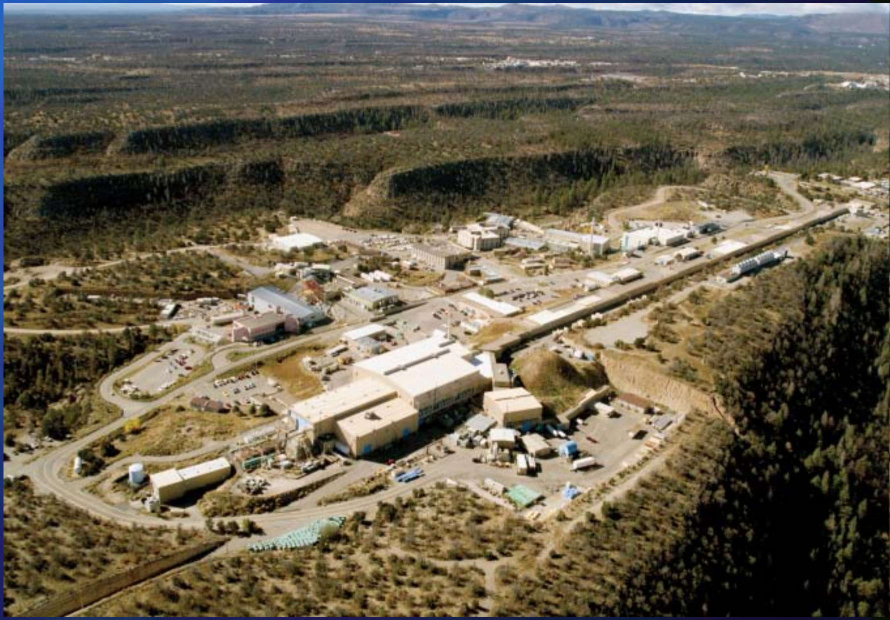


A new method for imaging nuclear threats using cosmic ray muons
C. L. Morris, Jeffrey Bacon, Konstantin Borozdin, Haruo Miyadera, John Perry, Evan Rose, Scott Watson, Timothy White, Derek Aberle, J. Andrew Green, George G. McDuff, Zarija Lukić, Edward C. Milner

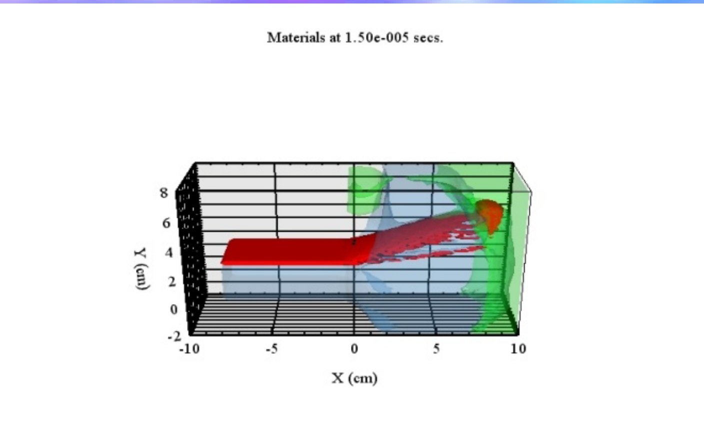
Proton Radiography



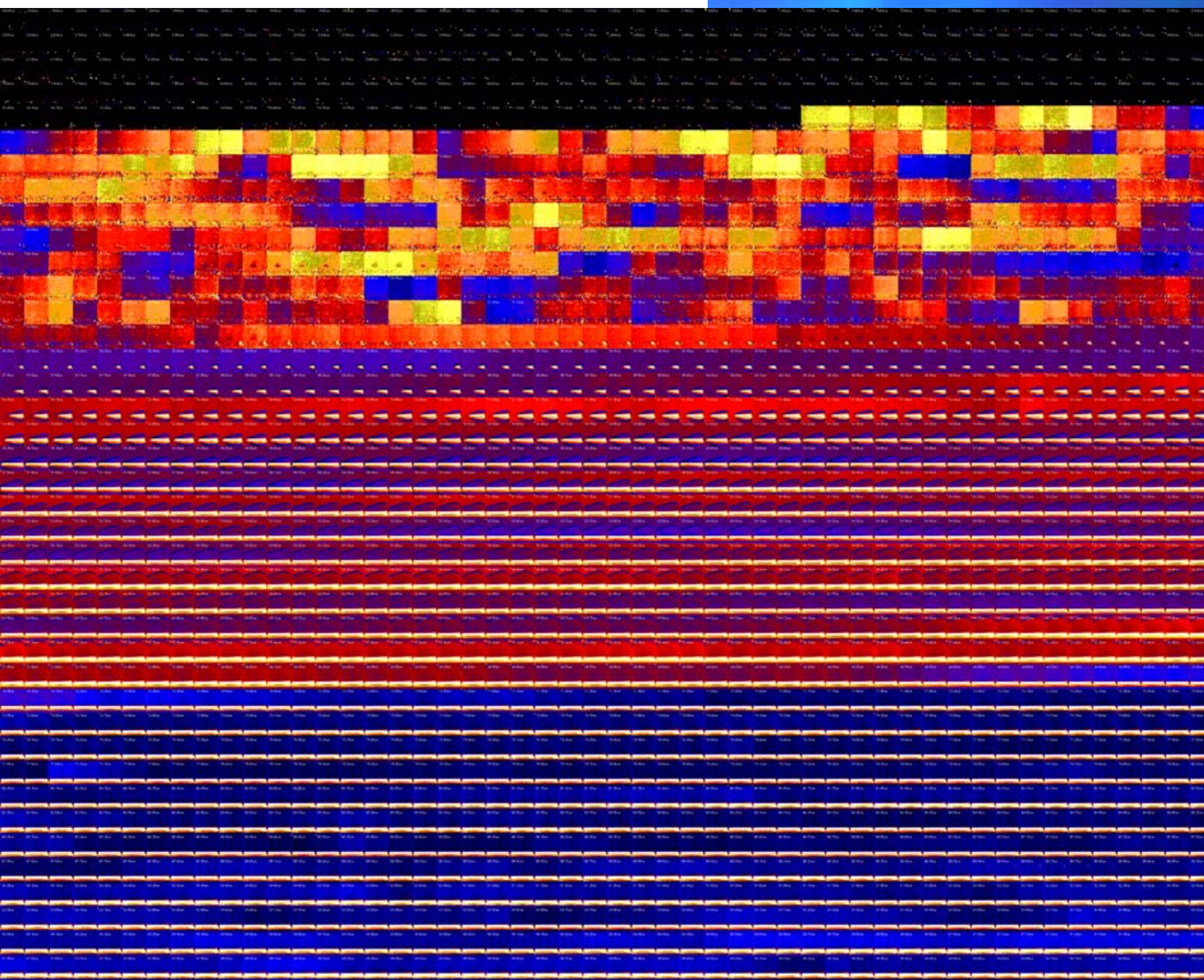
- Using charged particles allows beam focusing to match object size.
- Large quadrupole electromagnets focus 800MeV pulsed proton beam.
- RF accelerator creates a large number of individual beamlets suitable for dynamic movies.

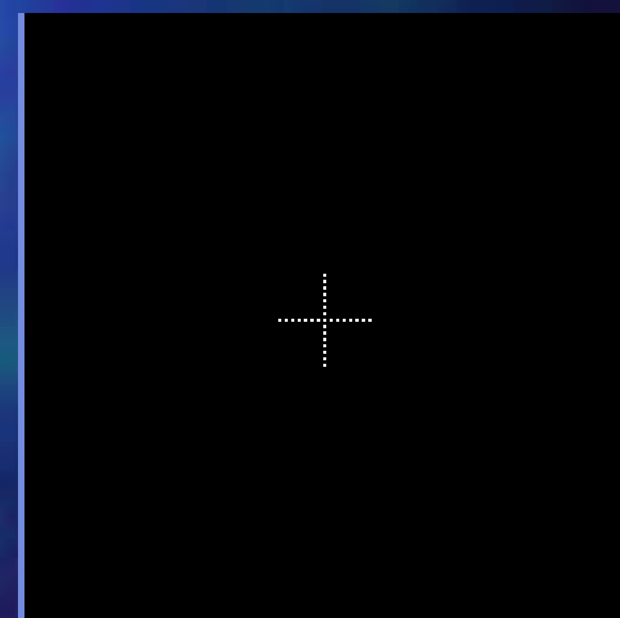


MOXIE Proton Radiography



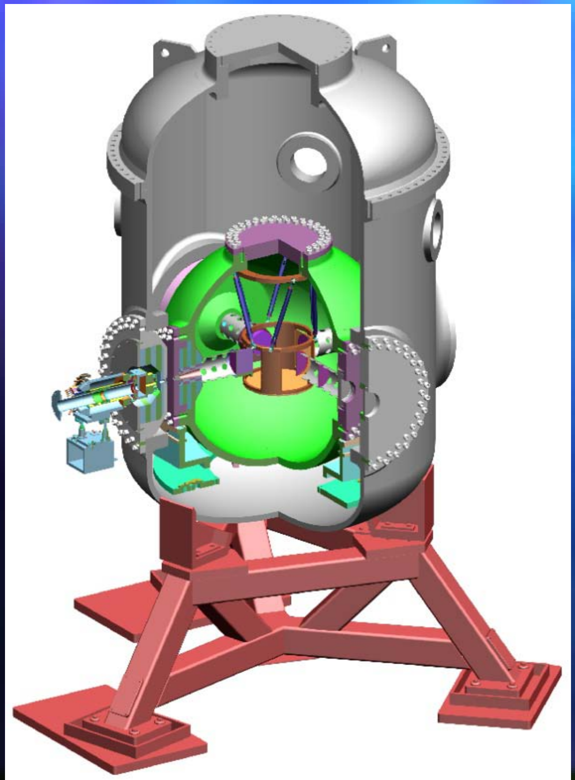
- Movie shows a detonation of an aluminum flyer plate experiment at LANSCE.
- Each frame is 50ns duration.
- Flyer plate is moving ~2km/sec.
- 100μs long movie images material dynamics from detonation to extinction.

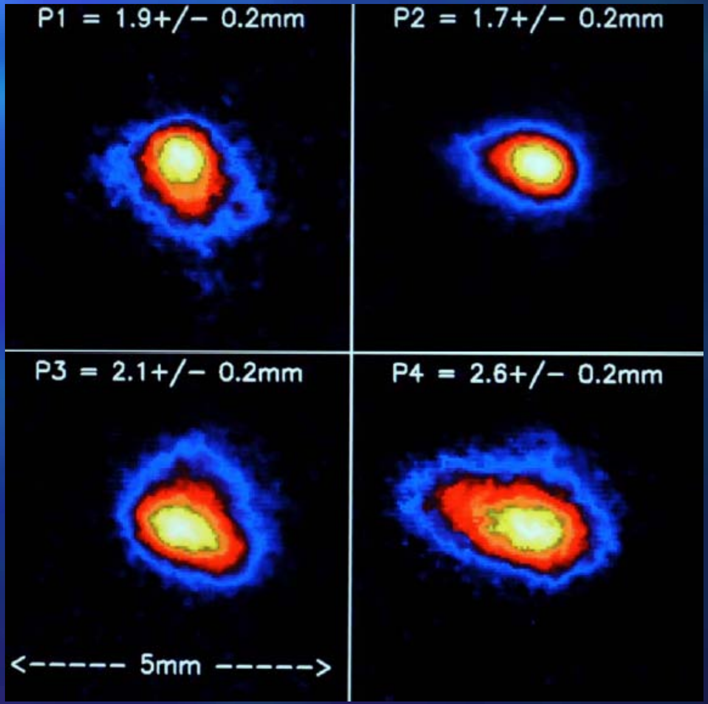




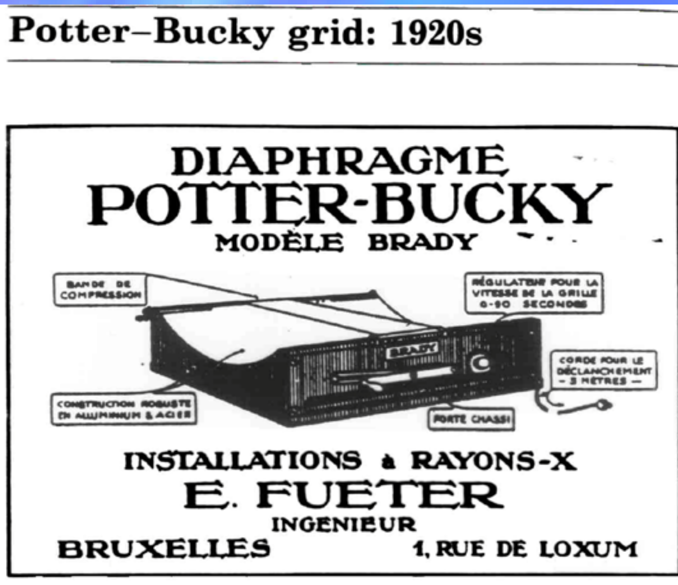
Spot Size Pinhole Camera

- Measures pulsed x-ray source at DARHT.
- Uses unique, plastic scintillator loaded into photo-etched tungsten matrix.
- Capable of nanosecond-time-scale radiographic spot size characterization.

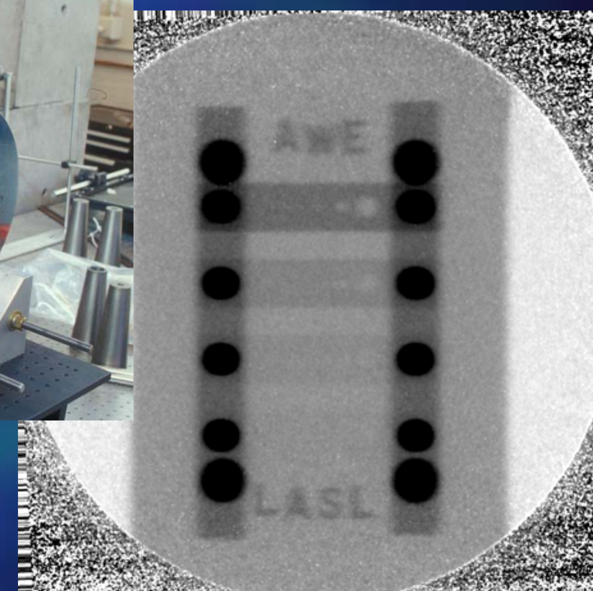




Megavolt Bucky Grids

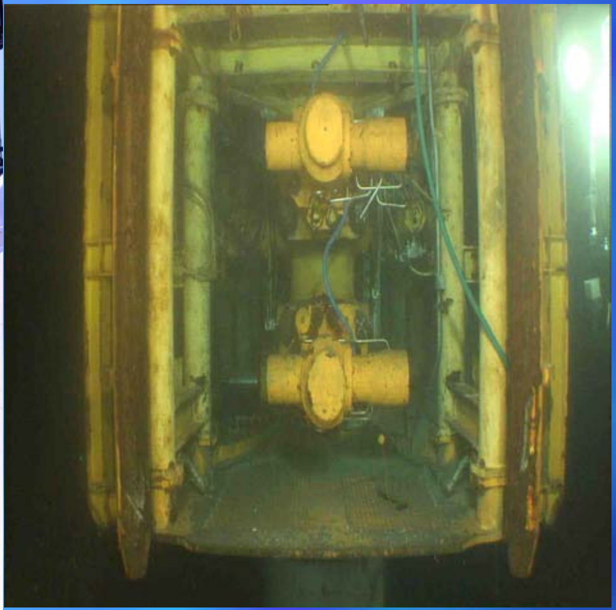


- Precision manufactured using cast and/or etched tungsten (Tecomet, Mikrosystems).
- High aspect ratios (>400:1).
- Demonstrated >1000:1 gauging sensitivity through 14” thick steel.

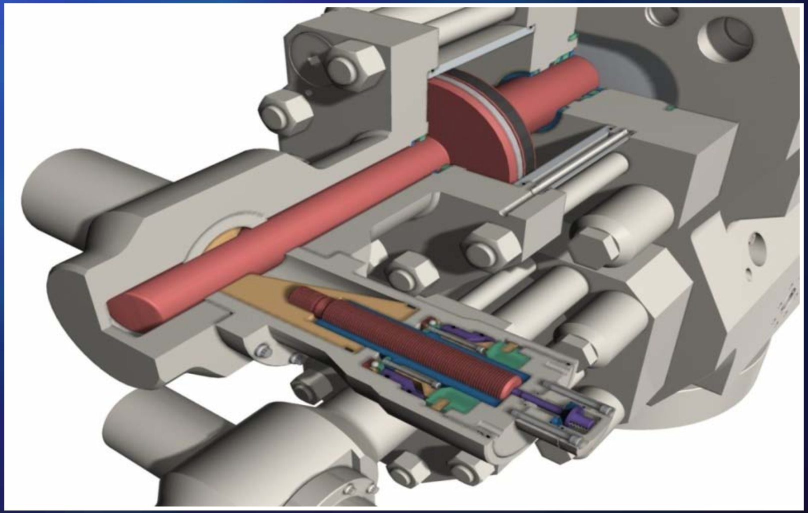


Design, Fabrication and Testing of a Large, anti-Scatter, Grid for Megavolt γ-Ray Imaging. 2005 Nuclear Science Symposium.

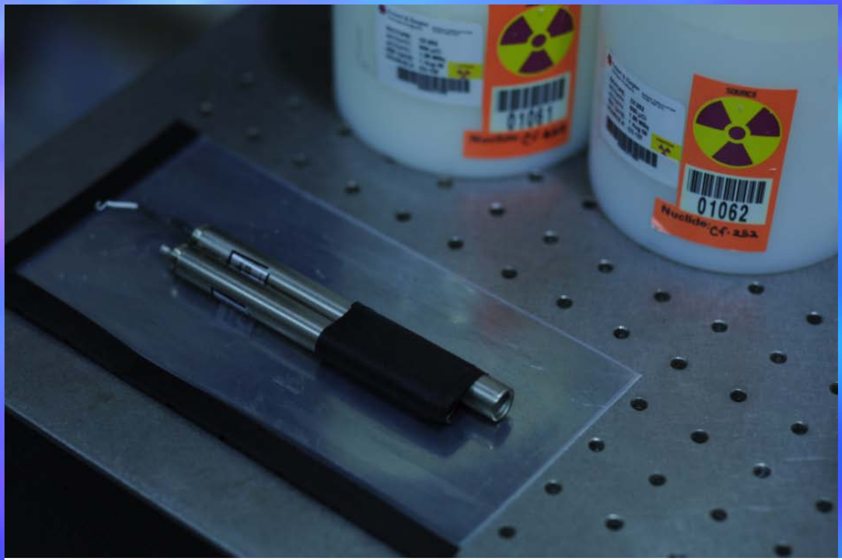
Deep Sea Radiography



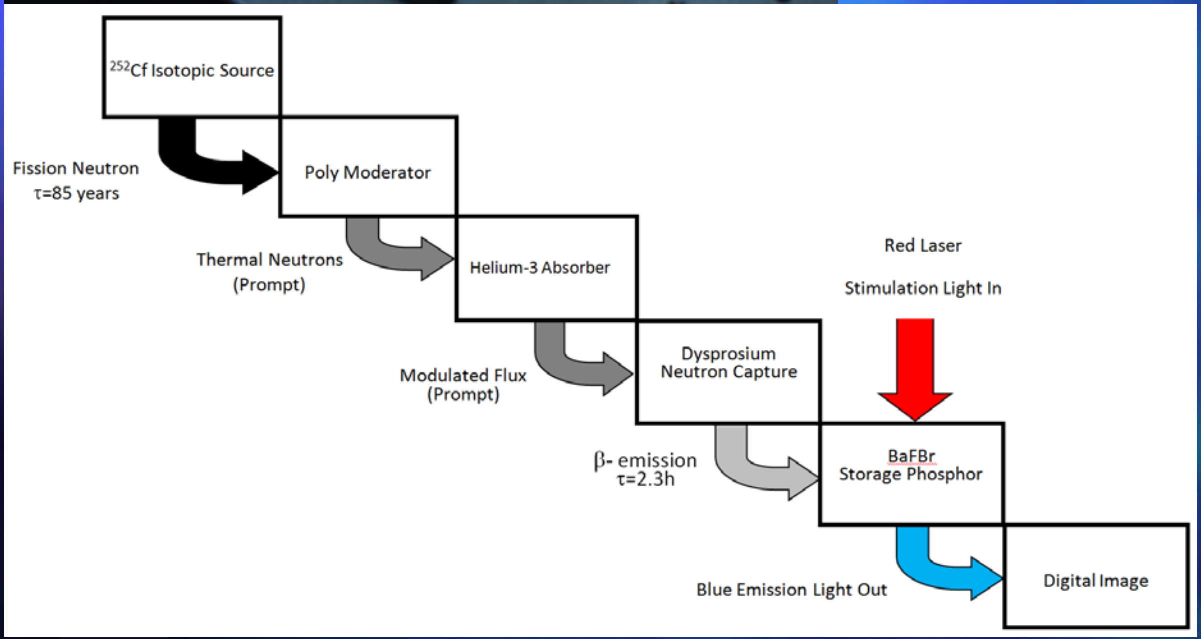
- Deep water radiography (5000ft).
- "Chu at one point pushed the idea of using gamma rays to peer into the blowout preventer to determine if the valves were closed. The suggestion elicited snickering and Incredible Hulk jokes. 'They weren't hot on his ideas', said a senior White House official. 'Now they are.'" – Washington Post

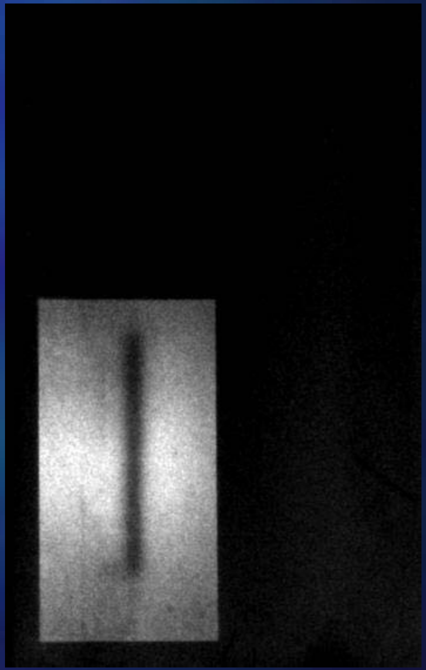


3-He Thermal Neutron Radiography



- Showed high contrast on 3-He gas in metal container.
- Unique use of Cf-252, dysprosium sheets and helium-3.
- Recently demonstrated with giant resonance photo-neutrons.

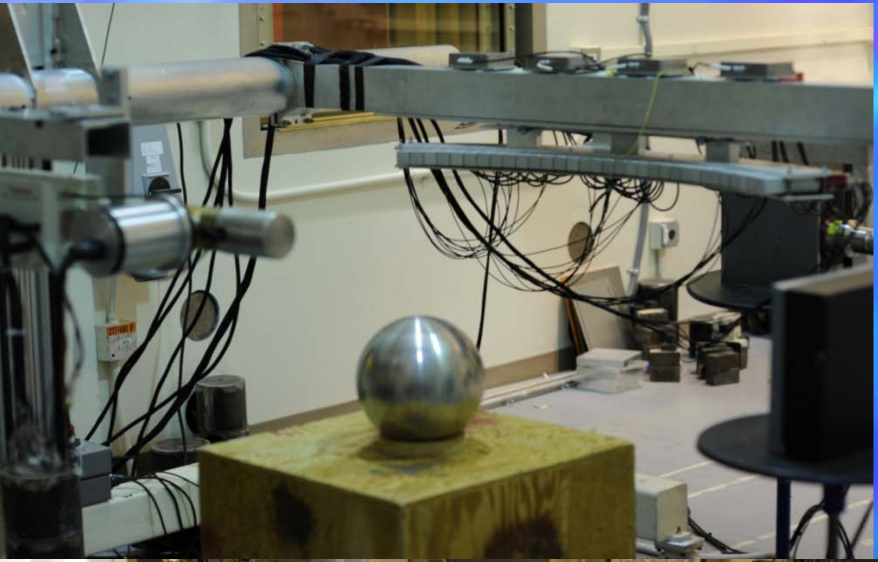




The Use of 3-He as a Gas Contrast Agent in Neutron Radiography(U). LA-UR-12-24389. The All Russian Research Institute of Automatics (VNIIA) Portable Neutron Generator and Technology Conference. 2012. Invited Paper

Berger, H., ed. Practical Applications of Neutron Radiogrpahy and Gaging. ASTM. STP586. 1976.

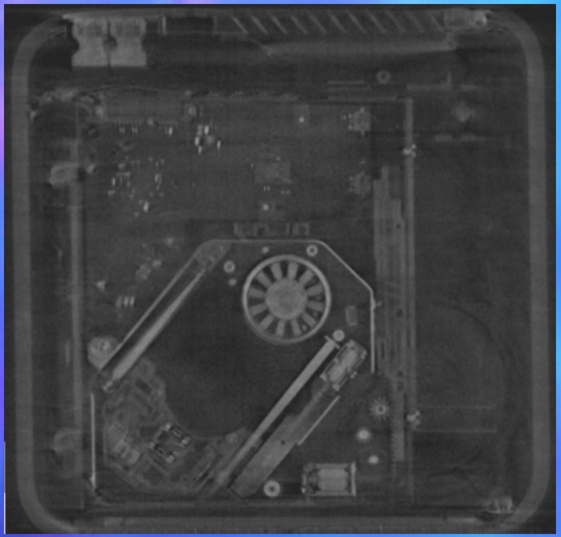
Fast Neutron Radiography With ORNL



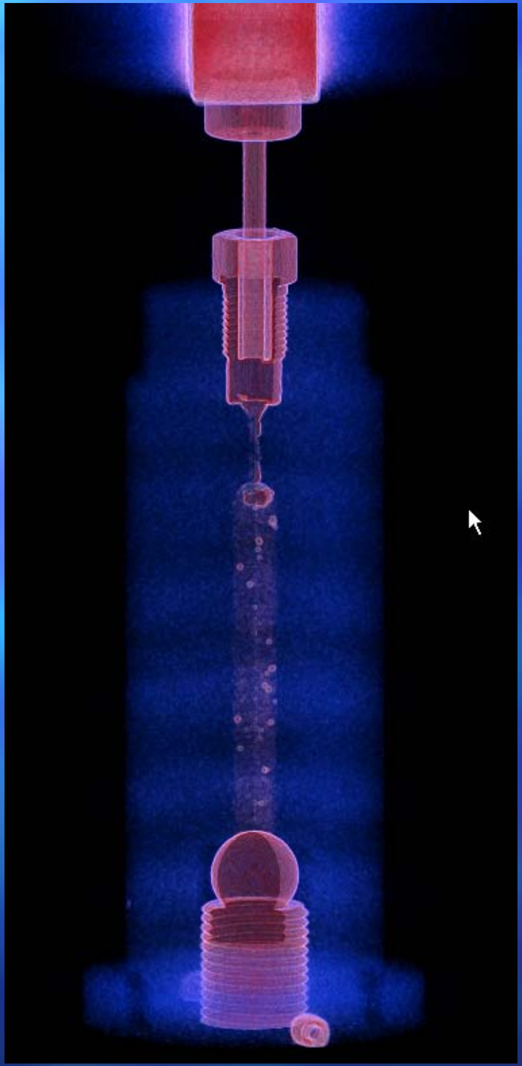
- Used associated-particle technique to radiograph through very thick objects.
- 14MeV DT neutron generator source.
- 14MeV neutrons can penetrate about twice the high-Z material as MeV γ-rays.
- Collaboration with John Mihalczo of ORNL.
- Material identification and thick object radiography demonstrated.

L. E. Ussery, C. L. Hollis. Design and Development of the Associated Particle Technique. LA-12847. Los Alamos National Laboratory. 1994.

Neutron Tomography



Neutron tomograph slice of a Mac mini.



Tomograph of high pressure rock core

LANSCE Flight Paths

- Flight path 5: Thermal and Epi-Thermal Neutrons
- Flight path 15R: 1MeV to 800 MeV

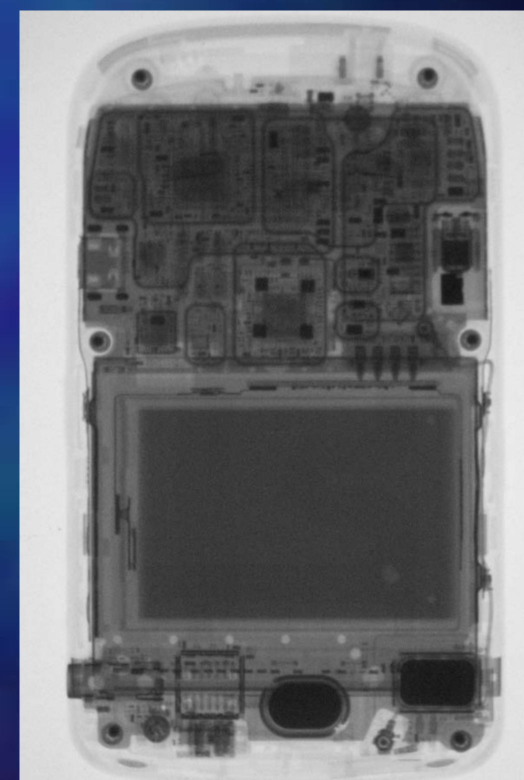
Computed Tomography

- Varian 25x20cm, & Perkin Elmer 40x40cm.
- 3 axis, 200kg motion control.

X-Ray Radiography and Computed Tomography Capabilities at AET-6. Los Alamos National Laboratory. LA-UR-12-00030. 2012.

MiniMAX Detector Technology

- Turns handheld camera into a lightweight, compact, storage phosphor scanner.
- Completely replaces mobile, wet film lab.
- It is now literally possible to carry an entire x-ray system in your hands.



MiniMAX: Miniature, Modular, Agile, X-ray System (U).
SPIE Defense Security & Sensing Conference. 2012.

Questions?

“Quantum Limited” Imager